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The Use of Fertilizers on Iowa Soils

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THE USE OF FERTILIZERS ON IOWA SOILS

A broadcast lime and fertilizer distributor

AGRICULTURAL EXPERIMENT STATION
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THE USE OF FERTILIZERS ON IOWA SOILS

By W. H. Stevenson and P. E. Brown

Experimental work conducted by the Soils Section of the Iowa Agricultural Experiment Station and the cooperative field experiments have indicated that certain fertilizers are needed on many Iowa soils and that they can be applied with profit. There are many soils, however, which cannot be reached by such tests and there are many problems connected with the use of fertilizers on individual farms which can only be solved by the farmers themselves.

Simple tests on the farm are of value in determining the need of and the profit which may be secured from the use of certain fertilizers. This circular attempts to present briefly facts regarding fertilizers and their use in Iowa. We hope farmers will become interested in testing the value of these materials. A knowledge of the facts, we believe, will aid in preventing a waste of money and energy thru the use of inferior and unprofitable fertilizers.

WHAT ARE COMMERCIAL FERTILIZERS?

Commercial fertilizers are materials that contain one or all of the three essential elements of plant food, nitrogen, phosphorus and potassium, while complete fertilizers contain all three. These elements of plant food are referred to commercially as ammonia, phosphoric acid and potash.

Incomplete fertilizers may be divided into three groups, nitrogenous, phosphatic and potassic. Of the many different fertilizers on the market, only those which are important in Iowa or which may be of use in the state are described in this publication.

NITROGENOUS FERTILIZERS

Incomplete nitrogenous fertilizers may be divided into three groups, (1) the nitrates, containing the element in a form directly utilizable by plants; (2) ammonium salts, which must usually be changed to nitrates before they can serve plants; and (3) organic nitrogenous compounds which require time and the action of bacteria to convert the nitrogen into a form available to plants.

Nitrate of Soda. The most important nitrate fertilizer, comes mainly from Chili and is called "Chili saltpeter". Large amounts are used annually in this country. The commercial nitrate ($NaNO_3$) is about 95 percent pure. It contains about 15 to 16 percent nitrogen, all in an immediately available form.

Calcium Nitrate. A commercial material manufactured by causing the nitrogen of the air to unite with oxygen in an electric arc furnace. The product is then passed thru milk of lime and calcium nitrate ($Ca(NO_3)_2$) is formed. It contains some lime and usually averages 12 to 14 percent nitrogen. It is equal to sodium nitrate in effectiveness, having its nitrogen in an available form, but it is not as generally used owing to its higher cost and to the difficulty in handling it. It takes up water rapidly and must be shipped in air-tight containers. It is diffcult to apply to soil.

AMMONIUM SALTS

Ammonium Sulfate. It is the most important ammonium, salt—a by-product in the manufacture of illuminating gas and coke. It contains about 20 percent of nitrogen or 24 percent of ammonia. Ammonium sulfate ($(NH_4)_2SO_4$) has been found to be about nine-tenths as effective as sodium nitrate. It is used extensively as a fertilizer and is very effective. It makes soils acid, however, and when used, special care must be taken to keep up the lime content of the soil.

Calcium Cyanamid. This fertilizer is also manufactured from the nitrogen of the atmosphere. It contains about 15 percent nitrogen. It must be applied a short time before seeding in order that the nitrogen may be changed into an available form. It is frequently used in the manufacture of complete commercial fertilizers.

ORGANIC NITROGENOUS FERTILIZERS

Waste products from slaughter houses are the chief organic nitrogenous materials used as fertilizers.

Concentrated Tankage. It consists of a mixture of slaughter house refuse from which the fat has been removed by cooking in tanks under pressure. The waste water from the cooking of bones and refuse is evaporated and added to the material, thus giving a higher content of nitrogen. The nitrogen content is quite variable, often being more than 12 percent. The phosphorus content is low. When the refuse alone is used the product is known as mixed tankage and contains 4 to 9 percent nitrogen and 3 to 12 percent phosphoric acid. It is used extensively in the manufacture of complete fertilizers.

Bone Tankage. This material consists of steamed bones with some meat. It contains 4 to 12 percent nitrogen and 7 to 20 percent phosphoric acid.

Dried Blood. One of the most important organic nitrogenous fertilizers. It is made by evaporating, drying and grinding the blood. Many grades are on the market and the composition is quite variable. The better materials contain 10 to 13 percent nitrogen while the poorer grades are often as low as 5 percent.

Meat Meal. Consists of the dried and ground inedible portions of the animal carcasses with the fat extracted. It varies widely in composition, containing from 10 to 14 percent nitrogen and 3 to 4 percent phosphoric acid. It is used in the manufacture of complete fertilizers.

Cotton Seed Meal. The product remaining when the oil is extracted from cotton seed. It contains about seven percent nitrogen and is often used as a fertilizer, but is so valuable as a feed that its use as fertilizer is restricted.

PHOSPHORUS FERTILIZERS

Phosphorus fertilizers include both natural and manufactured products. The natural fertilizer, rock phosphate, contains the element in a slowly available form; the manufactured fertilizer provides phosphorus in a form readily available to plants.

Rock Phosphate. Found in natural deposits in various parts of the country, notably, South Carolina, Tennessee, Florida, Idaho, Wyoming and Montana. It is prepared for the market merely by grinding the rock. It contains from 10 to 14 percent phosphorus or 20 to 28 percent phosphoric acid. In some cases, the content of phosphorus may be as low as 8 to 9 percent, with a larger content of iron and alumi-

num. The finely ground material, known as "floats", is used directly as a fertilizer. It is used also in the manufacture of acid phosphate.

Basic Slag. A waste product obtained in the manufacture of steel from iron ore. It is also called Thomas slag. It is variable in composition, averaging 16 to 19 percent phosphoric acid. It contains some calcium oxide and some calcium carbonate. It is a valuable phosphorus fertilizer but is scantily available and is unimportant in Iowa.

Bone Meal. A very valuable phosphorus fertilizer but the supply is so small that it cannot be recommended for general use. The fat is removed by steaming the bones under pressure and the product is finely ground. It contains from 9 to 12 percent phosphorus, or 22 to 28 percent phosphoric acid and also a small amount of nitrogen.

Acid Phosphate. This is the most important manufactured phosphorus fertilizer. It is made by treating raw rock phosphate with sulfuric acid. The product consists of a mixture of a soluble phosphate and calcium sulfate (gypsum). Acid phosphate has a phosphorus content of 6 to 7 percent or 12 to 14 percent phosphoric acid and thus it contains half as much of the element as rock phosphate. The phosphorus, however, is in an available form, that is, it may be utilized directly by plants. Hence, acid phosphate has a quicker action on soils, and it is used in smaller amounts than the rock. It is extensively used as an incomplete fertilizer to supply the element phosphorus, but it is also used in the manufacture of complete commercial fertilizers.

POTASSIUM FERTILIZERS

The chief source of commercial potassium fertilizer at the present time, is the Stassfurt deposits in Germany. The chief fertilizing substances derived from these deposits are kainit, muriate of potash and sulfate of potash.

Kainit. A natural salt secured from Stassfurt, composed of potassium sulfate and some chlorides. As placed on the market, it contains about 10 percent potash, or 8 percent potassium. It is much used as a fertilizer but is considered quite inferior to the muriate or sulfate.

Muriate of Potash. The muriate or chloride of potash (KCl) is a purified product from the potash mines. It contains 40 to 50 percent potash, or 32 to 41 percent potassium. It is a very important potash fertilizer and is extensively used alone, in mixtures and in the manufacture of complete fertilizers.

Sulfate of Potash. A manufactured product from the Stassfurt mines. It averages 40 to 50 percent of potash or 32 to 41 percent potassium. It contains potassium in an available form (K_2SO_4) and is much used as a fertilizer. Either the muriate or sulfate may be employed where available potassium is needed for plant growth. These materials are much more desirable for use than kainit. There is very little choice between the two compounds under Iowa conditions.

COMPLETE COMMERCIAL FERTILIZERS

Complete commercial fertilizers contain nitrogen, phosphorus and potassium, in varying amounts. They are manufactured fertilizers and hence many different ones are on the market.

Complete fertilizers are commonly sold under brand names which refer to the content of the three elements. For example, a 2-12-2 fertilizer (one of the common complete fertilizers on the market) contains 2 percent ammonia, 12 percent available phosphoric acid and 2 percent potash.

Fertilizer laws in most states protect the buyer from fraud and the analysis given by the manufacturer, called the guarantee analysis, may usually be depended upon to show what the fertilizer contains. This is certainly true if the fertilizer is purchased from a reputable company. Fertilizer manufacturers, however, cannot guarantee what the results may be on crop yields. Numerous brands of fertilizer are offered which have been made up to meet the needs, or supposed needs, of certain crops, or to supply the deficiency in a particular class of soils. Thus there are brands for wheat on sandy soils, for the same crop on loam soils, or on clay soils. Often these special brands have been prepared as a result of actual experience in the growing of certain crops on the particular soils. However, results may vary widely on the same crop on soils under different conditions.

Fewer brands of complete fertilizers are now on the market than formerly. There are also fewer so-called low grade materials. The latter contain small amounts of some or all of the fertilizing constituents and are much less desirable for use than the high grade materials.

It is believed that fertilizers should contain at least 16 percent total plant food; that is, their total content of ammonia, phosphoric acid and potash should equal 16 percent. The 2-12-2 brand is a typical example.

Until more definite information is secured regarding the brands of fertilizers to use under special conditions, farmers should secure the ones recommended for the crops they are growing and for the particular soils on their farms. In addition, field tests should be made to determine whether these brands are giving the most profitable results. Several different brands may be compared and the one chosen for general use which is the most economic. For general farm crops, on the average Iowa soil, probably the 2-12-2 brand is the best for testing purposes, but for truck crops and other special crops, other brands are undoubtedly more desirable.

INDIRECT FERTILIZERS

Some fertilizing materials are applied to soils, not to supply any of the three essential plant food constituents, but to bring about desirable conditions in the soil for plant growth by increasing the production of available plant food. Lime and gypsum are the indirect fertilizers of most interest at the present time.

LIME

Iowa farmers well know the importance of liming acid soils in order to secure the best growth of crops, particularly legumes. About 75 percent of the land in Iowa has been found to be acid in reaction and in need of lime. Thousands of tests are made each year by farmers, county agents and by the Soils Section of the Iowa Agricultural Experiment Station. The methods of testing soils to determine their needs for lime, the kind of lime to use, the beneficial effects on various crops, and many other points connected with soil acidity and liming are taken up in other publications. Farmers may have their

soils tested free by sending small samples to the Soils Section of the Iowa Agricultural Experiment Station.

THE KIND OF LIME TO USE

The various forms of lime which may be used for soils include ground limestone, burned or slaked lime, waste lime from sugar factories, pulverized clam shells and refuse from carbide light plants. Ground limestone and limestone screenings are usually the most desirable for use in Iowa, chiefly because either may be secured cheaply in this form. Any of the materials, however, are satisfactory if they can be secured at low cost. Burned lime should be slaked before it is applied to the soil and very large applications should not be made at one time because undesirable effects may occur. Limestone, even in large amounts, does not have any injurious effects.

HIGH GRADE LIMESTONES ARE PREFERABLE

Various grades of limestone screenings and ground limestone are available in the state. The great majority are quite satisfactory. Some, however, are less desirable owing to the presence of large amounts of impurities and the consequent low content of calcium carbonate or lime. If poor grades of limestone are used, much larger amounts must be applied in order to secure the same effects. Whenever possible, the higher grade materials should be used, provided the difference in cost is not too great. It is much more expensive to apply large quantities of limestone because freight costs generally constitute a large part of the expense of liming.

Many of the limestones available in Iowa contain calcium carbonate only, while others contain magnesium carbonate along with the calcium. If limestone contains a reasonable content of carbonates, anywhere from 78 to 90 percent, it may be considered entirely satisfactory.

The fineness of limestone particles is very important, because if they are too coarse, the action on the soil will be too slow. For best results, limestone should consist of at least 60 percent dust and the remainder should be not larger than a pea in size.

FARM GRINDING OF LIMESTONE

In some localities, the cost of purchasing, hauling and shipping ground limestone from a commercial quarry is very great. The shipping cost is, of course, the large item. When lime rock outcrops occur in such a locality, the desirability of farm grinding becomes an important question.

The advisability of grinding limestone on the farm depends upon the quality of the local rock, the cost of quarrying and grinding, and also upon the cost of securing the limestone for agricultural use from a commercial quarry. The Soils Extension Service of Iowa State College, after a rather comprehensive study in Iowa and other states, concluded that it may be advantageous to practice home grinding in some cases. The following method is suggested for determining the desirability of the practice, assuming these figures:

Average distance to nearest shipping point—5 miles.
Roads good in summer and fall; very poor in spring.
90% limestone delivered from quarry at $1.70 per ton.
Quality of local rock—85%.
Average haul from local deposit—1½ miles.
Limestone wanted for winter and spring use.

The calculation may then be made thus;

90% limestone delivered at shipping point	$1.70	per ton
5 mile haul, under favorable conditions	1.50	" "
Cost at farm	3.20	" "
Cost to quarry and grind local rock (labor, power and crusher charge)	2.25	" "
Cost to haul rock 1½ miles, about	0.50	" "
Cost at farm	2.75	" "

In this case there is a saving of 45 cents per ton, plus the convenience of having the limestone when needed and in the quantities desired. Account should be taken of the fact that a large part of the farm grinding cost is labor for which the farmer is allowed pay. Similar pay is allowed the farmer for hauling the limestone from the shipping point to the farm.

GYPSUM

Recently considerable interest has developed in the application of gypsum because of the beneficial effect it may have on crop growth due to its indirect effects in liberating available plant food. It may also increase crop yields because of the sulfur which it contains, inasmuch as there is a possibility of an insufficient sulfur supply in the soil. Many analyses indicate that there is not a large amount of sulfur present and as it is required for the best plant growth, a sulfur fertilizer will certainly be needed in the future and may be of value now. Furthermore, tests have shown that gypsum may liberate certain plant food elements in the soil, changing them into an available form.

FIELD TESTS WITH GYPSUM ARE DESIRABLE

Recent field experiments in Iowa have shown some value from the use of gypsum, especially where legumes were grown. Some soils have responded to gypsum, while others have not. The general use of gypsum on Iowa soils cannot be recommended at the present time. Farmers who are interested are urged to test gypsum on a small scale so as to determine whether it will prove profitable for larger use. Such tests should be carried out with legumes as these crops are most apt to respond. Gypsum should be applied at the rate of 200 pounds per acre, and disced in before the crop is planted. It should not be used on land which is acid in reaction until an application of lime has been made. Gypsum does not take the place of lime and it will not remedy acidity in the soil. On the other hand, it will not make the soil acid nor have any other injurious effect on the land.

HOW TO TELL WHEN TO USE FERTILIZERS

The question is often asked—"How is it possible to tell when fertilizers are needed on land?" There is no simple method of determining the needs of soils for fertilizers. If poor crops are secured year after year, apparently something is wrong with the soil. But it is often very difficult to determine just what is lacking. The experimental work of the Soils Section has been planned to determine the needs of the various soils of the state. Altho many more years of experimental work are needed certain general conclusions have al-

ready been reached, which have been summarized in another publication.[1] Briefly, the general needs of Iowa soils include cultivation and drainage, the proper rotation of crops, manuring and green manuring, liming and the use of phosphates and other fertilizers.

WHAT SOIL ANALYSES SHOW

The idea that a chemical analysis of a soil shows its needs is still held by some farmers. It does not do this. It merely indicates what may be the fertilizer needs. Such an analysis does give the total plant food present. But plants cannot use all of the plant food in the soil; they can only utilize the portions which dissolve in water, or what is termed the "available constituents". The amount of soluble or available plant food is much smaller than the total content. There may be a very large amount of plant food present but only a very small amount available to plants. If the total amount of any one constituent in a soil is small, there certainly will be a relatively small amount of that element present in an available form. Hence, the analysis of a soil may indicate that there is need of using fertilizer carrying the particular element which is deficient.

Many analyses have been made of various Iowa soil types and reported in other publications. These analyses show that phosphorus is present in small amounts and may be deficient for crop needs. The experiments which have been conducted have been centered around phosphorus in the attempt to determine how the soils of the state should be fertilized. Other fertilizer constituents may be needed on some soils, but soil analyses have seldom shown these needs. The only way to determine the value of potassium and nitrogen is to apply them to small areas and measure the increases in crop yields secured from them.

FIELD TESTS THE ONLY SURE WAY TO LEARN SOIL NEEDS

While a soil analysis is of value, the only sure test of soil requirements is to apply a certain fertilizer and determine its effect on the crop.

Ninety-four cooperative soil experiments are now being carried out by the Soils Section of the Iowa Agricultural Experiment Station in cooperation with farmers. These fields are located in various parts of the state in counties where soil surveys have been completed. They consist of 9, 13 or 15 plots, one-tenth of an acre in size. These plots receive applications of manure, lime, acid phosphate, rock phosphate, a complete commercial fertilizer and in some cases, muriate of potash. The manure and lime are considered basic applications and the other materials are supplied in addition. This plan of fertilization represents the live stock system of farming and it is followed on one-half of the plots in each field. The other half of the series is treated with crop residues as the basic treatment representing the grain system of farming.

The manure is applied at the rate of eight tons per acre once in a four-year rotation. The crop residue treatment consists of the return to the soil of the second crop of clover, the corn stalks and the grain straw. The lime is applied in amounts shown to be necessary according to tests which are made of the soil. The acid phosphate is applied at the rate of 150 pounds annually, the rock phosphate at the rate of

1 Bul. 213, Iowa Agr. Exp. Sta.

2,000 pounds once in a four-year rotation, the complete commercial fertilizer, a 2-12-2 brand, at the rate of 202 pounds annually, and the muriate of potash, when used, at the rate of 25 pounds annually. These tests are carried out under various rotations, namely those which the farmers happen to be practicing.

Many of these tests show certain fertilizers, to be of value on some soils. The results are given in Bulletins 213 and 221, Iowa Experiment Station.

These field experiments do not answer all the questions, however, which farmers are asking and they do not show what may be the best fertilizer treatment for other soil types. For these reasons farmers are urged to test their own soils.

FARMERS MAY TEST THE NEEDS OF THEIR SOILS

Simple fertilizer tests may be carried out on any farm. The plan followed in the soil experiment fields, (described above) may be followed, but this plan may be modified in many ways to fit the individual conditions. In any test, the first point to consider is the location. The soil should be representative of the area to be tested. The surface soil and subsoil conditions should be examined, the topography should be characteristic, and the previous history of the area should not show any variation from the common practice of cropping and treatment. The plots should all be of the same size; they may be one acre, one half acre, one-quarter acre or one-tenth acre in size. The one acre plots are generally the most convenient. Tenth acre plots may be two rods wide and eight rods long. The plots should be divided by seven foot strips to prevent a mixing of the treatments. This allows for two rows of corn and one seven-foot drill. The location of the plots may be fixed by placing a stake in the fence row to mark the outer corner of the first plot. Other stakes are then placed to show the width of the plots and the width of the division strips. A plan of the test should be drawn up and careful records of the results should be kept on some convenient form.

PLOT TESTS MAY BE MADE

The test may include 13 plots having the same treatments which are used in the Station cooperative fields described above.

1. Check.
2. Manure.
3. Manure+lime.
4. Manure+lime+acid phosphate.
5. Manure+lime+rock phosphate.
6. Manure+lime+complete commercial fertilizer.
7. Check.
8. Crop residues.
9. Crop residues+lime.
10. Crop residues+lime+acid phosphate.
11. Crop residues+lime+rock phosphate.
12. Crop residues+lime+complete commercial fertilizer.
13. Check.

For a livestock farm the first seven plots of the series may be used and the last seven for a grain farm. If it is desired to test potassium, then there may be 8 or 15 plots, the additional plots receiving manure, lime, acid phosphate and muriate of potash and crop residues, lime, acid phosphate and muriate of potash.

The treatments applied should be in the amounts used in the cooperative fields. The soil should be tested for acidity and the amount of lime should be used which the test shows is necessary.

It is always desirable to compare the effect of complete fertilizer with acid phosphate, as the latter material may prove of equal value.

STRIP TESTS ARE OFTEN DESIRABLE

Even simpler tests than those suggested may be made by applying fertilizers in strips across a field. Such strips should be at least 28 feet wide in order to include 8 corn rows and permit using a seven-foot drill. Such strip plots should be located by the use of stakes in the fence row and careful records should be kept just as in the other tests. If no borders are left between these strips, then the yield of the six inner rows of corn should be taken and borders should be left when the small grains are harvested. Any fertilizers may be tested by such strip tests.

The land may receive manure and lime as basic treatments with the particular fertilizer applied in addition, or the fertilizer may be applied alone. Comparison may then be made with adjacent untreated strips. Satisfactory fertilizer tests cannot be secured, however, if the strips do not receive the same general treatment which is given the adjoining land. In all tests on the farm, the use of a good crop rotation should be practiced, if the results are to be of value.

By following the suggestions made here, any farmer may learn what his soil needs and what particular fertilizers should be applied. By keeping accurate records of yields and cost of the materials he may reach a definite conclusion regarding the profit which he may secure from the treatment. Aid and suggestions can always be secured from the Soils Section of the Iowa Agricultural Experiment Station in planning and carrying out such tests.

WHAT FERTILIZERS DO

Fertilizers are generally used to increase crop yields, but they may improve the quality of the product as well as increase its quantity.

Different fertilizing materials exert different effects on crops, both in quantity and quality of production. Nitrogenous materials bring about quick and vigorous growth of stalks and stems. Phosphatic fertilizers hasten maturity and help fill the grain or fruit. Potash makes the straw and stalks stronger and helps to fill the grain or fruit. Complete commercial fertilizers may bring about all these effects on the crop, the proportionate amounts of the various constituents determining just what the final action will be. This is the reason for the utilization of the different brands of fertilizers which are on the market.

If it is desired to hasten maturity, then more phosphate is required. If maturity should be delayed, then more nitrates should be employed. The kind of crop should of course be the primary consideration. Grain crops like wheat need more phosphate and more potash, while hay crops which are grown for stalk or stem need more nitrogen. Potatoes and other root crops require more potash and less nitrogen. Too much nitrogen on grain crops will cause the development of the straw at the expense of the grain. Similarly with root crops, too large an amount of nitrogen will cause an over-development of tops with a resulting decrease in root growth. The lodging of grains which often occurs on newly cultivated, rich, black soils is due to the large amount of nitrogen present. Nitrogen is needed in an available form for the early growth of crops, hence it is often desirable to make a top-dressing of nitrogen in the form of sodium nitrate to stimulate the early development of a crop. Often, too, a small top dressing of a potassium

fertilizer may be of value. After the crop has a start, however, then it needs the phosphate, in order to hasten maturity and insure a good weight of grain.

WHAT FERTILIZERS SHALL BE TESTED?

The value of farm manure in increasing crop yields is so well known that there is no need of testing its effects. Farmers on live-stock farms should see that all the manure produced on the farm is properly stored and applied to their land. This fertilizer is worth more than two dollars per ton on almost any Iowa soil. On the grain farm the use of legumes as green manures is necessary. These are basic treatments and should always be practiced.

Soils which are acid need lime. Simple laboratory tests indicate the amount needed. The value of lime in increasing crop yields may be ascertained by applying it to a portion of a field, or by carrying out a strip test such as has been suggested. Lime should be considered as a basic fertilizing material for many Iowa soils.

The soil analyses, greenhouse tests and field experiments have indicated very conclusively that phosphorus is needed on many Iowa soils. Acid phosphate and rock phosphate are the two fertilizers which can be secured most readily and one or the other should be employed. The rock costs less per unit of phosphorus, but the smaller cost may not offset the slower action in the soil and the consequent smaller effect on crops. On some soils acid phosphate seems to be preferable. On others rock phosphate may be more desirable. Farmers are urged to test both materials if possible to determine for their own conditions which should be used. To determine whether the soil needs phosphorus, acid phosphate should be applied to a small area. When rock phosphate is employed, the soil should be well supplied with organic matter in order that the phosphorus may be made available.

Complete commercial fertilizers may be of value on some Iowa soils. Those interested are urged to test a good, high grade complete fertilizer on their land, comparing it preferably with acid phosphate. The 2-12-2 brand, used in the cooperative experiment fields, is a good one to test. Other brands may be more desirable for special conditions, and particularly for special crops. At the end of this circular will be found a list of fertilizers which may be tested on various soils and crops in Iowa.

Nitrogenous fertilizers are rarely needed in Iowa for general farm crops. Only in small amounts as top dressings can their use in tests be recommended. For such tests, nitrate of soda or ammonium sulfate should be employed, preferably the former. For truck or market garden crops, the more general use of nitrogenous materials may be very desirable.

Potassium fertilizers have been used only to a very limited extent in the state. Iowa soils are generally well supplied with potassium and it would seem that potassium fertilizers would not prove of value. In a few cases, however, muriate or sulfate of potash fertilizers have profitably increased crop yields. This is undoubtedly because the production of available potassium in some soils is too slow to keep the crops properly supplied. If muriate or sulfate of potash fertilizers are tested they should be applied in combination with acid phosphate. The potassium fertilizers mentioned may also prove of value when applied in small amounts as top dressings for some crops. For special crops, particularly truck crops, potassium carriers may be of

large value. They may be profitably tested in larger applications and in different ways on such crops.

Gypsum may be of value on some soils and testing its effect on such crops as red clover and alfalfa may prove profitable. If the soil is acid it should be limed before gypsum is applied.

FERTILIZERS DO NOT INJURE SOILS

When properly applied, fertilizers do not injure the soil. The old ideas that fertilizers rapidly exhaust the soil and that if once used their use must be continued indefinitely are erroneous. The land is not exhausted beyond the actual decrease in plant food caused by the larger crop yield, which the fertilizers bring about. A larger crop will of course take out more plant food than a smaller one. The larger the crop, the more need there is to supply necessary plant food, and hence any treatment which increases crops will lead to a demand for fertilizers. It is good business to produce high yields because they lower the cost of production even tho they remove larger amounts of plant food which must be replaced with fertilizers.

If proper tillage, drainage, manuring and liming are not practiced the fertilizer may not increase yields. The rational use of fertilizers does not make soils poorer; it actually makes them richer provided other essential treatments, such as those mentioned above, are practiced. This is true because there is always a residual effect from proper fertilization which may be apparent for several years. To learn whether fertilizers should be used, the only consideration is the value of the crop increase secured, taking into account the cost of production.

HOW AND WHEN TO APPLY FERTILIZERS

The question of how and when to apply fertilizers can not be answered in any general way for all materials. Each must be considered separately.

Rock Phosphate. The best time to apply rock phosphate is in the fall plowing it under with the clover sod, on land which is to be put to corn. Rock phosphate gives best results when plowed under with a large application of manure or with a green manure crop.

Rock phosphate may be applied satisfactorily by the use of a fertilizer or lime distributor. These machines give a broadcast application. The material may also be applied by using 100 to 200 pounds on each load of manure. The application should be made prior to plowing and thoroly incorporated with the soil, in order to produce available phosphorus.

Acid Phosphate. Acid phosphate should always be applied after the ground is plowed and is ready for seeding. Fall application should not be practiced except for fall seeded crops such as wheat. It provides the element phosphorus in a form directly utilizable by crops and hence does not need to be applied until the crop is seeded.

Acid phosphate may be applied broadcast by the use of a fertilizer distributor and even distribution should be secured. When broadcast, the fertilizer must be used in larger amounts. For general farm crops, a broadcast application of acid phosphate should consist of 125 to 200 pounds.

Acid phosphate may also be applied by the use of a corn planter attachment or a fertilizer attachment to the grain drill. When applied in this way, 100 to 150 pounds of phosphate should be applied an-

nually. The corn planter attachment places the fertilizer near the hill of corn and often in direct contact with the seed. Different attachments locate the fertilizer in slightly different positions relative to the hill. There is some difference in the effect of the fertilizer which seems to be determined by the exact location in which it is placed.

The best location has not been definitely determined but it seems that the fertilizer should be placed at the sides rather than to the rear of the hill. Placing the fertilizer at the side minimizes the danger of it injuring the germination of the seed. With some of the attachments on the market, it is difficult to make proper adjustments and the phosphate is sometimes dropped with the seed. When this occurs there may be a distinct injury to germination. Probably the most desirable results will be secured by placing the fertilizer in a strip 3 to 4 inches wide by 10 to 12 inches long, the seed being dropped in the center of the fertilized area and the fertilizer being thoroly mixed with the soil. Corn planter attachments which will place fertilizer in this way should be devised. There seems to be no injury to germination by this method. If acid phosphate is not broadcast with a fertilizer distributor, it is probably better to apply it with the fertilizer attachment on a grain drill, prior to corn planting. For small grains and clover acid phosphate is most satisfactorily applied by use of the drill fertilizer attachment. This method gives thoro distribution of the phosphate and no extra labor is involved. The fertilizer should not be applied with a drill or planter by mixing it with the seed in the seed box.

Complete Commercial Fertilizers. Complete fertilizers are applied at the same time and in the same way as acid phosphate. The amounts used may vary considerably, depending upon the particular brand which is employed. In general, the size of the application should be about the same as that of acid phosphate. When a comparison of a complete fertilizer with acid phosphate is to be made, then an amount of the former containing the same quantity of the element phosphorus as is supplied with the acid phosphate, should be used. Thus if 150 pounds of acid phosphate are applied, the amount of a 2-12-2 complete fertilizer should be 202 pounds. Like acid phosphate, complete fertilizers should be applied after plowing and just prior to seeding. They are best applied by the use of the fertilizer attachments on the grain drill, with the grain or ahead of the corn.

Top dressing with acid phosphate, with complete commercial fertilizers, or with such incompletes as nitrate of soda or muriate of potash, is accomplished by the use of the fertilizer distributors or by hand as in the case of gardens and lawns. It is rarely desirable to top dress with the first two materials, but the nitrate and the muriate are frequently used in this way. For pasture improvement, top dressing may often be a very desirable practice and in such a case, the fertilizer is applied and the pasture is then disced. If the pasture is to be re-seeded, it is first disced, the fertilizer is applied with the seed with the fertilizer attachment to the drill and the land is then harrowed at right angles to the direction in which it was disced.

Limestone. Limestone may be applied to the land at any time. Fall application is most desirable, however, provided the land has been plowed. Lime should always be applied on land after plowing and it should be thoroly disced in before seeding. When added in the fall, much time is allowed for the lime to act in the soil and to bring it into better condition for plant growth. Lime should not be spread in the winter on rough land because of the danger of it wash-

ing away. Limestone should not be shipped during the winter because it is likely to freeze in the cars and much difficulty may be experienced in unloading. Limestone is often applied in the spring, but in general this is not as desirable as fall application, and the latter is recommended whenever possible.

The application of lime to soils is particularly necessary for securing the best legume crop. Other crops in the ordinary rotation do not usually respond to liming nearly so much as legumes. Hence, it is desirable to apply lime just prior to seeding the legume. On corn stalk ground the lime is applied after plowing and is disced in If the land is not to be plowed, then the lime is applied at any time preceding seeding and is disced in. Top dressing with lime is sometimes practiced, but the application in this way on pastures and meadows is not generally profitable. If alfalfa stands are to be thickened, lime may be applied and disced in, previous to the seeding. Additions of lime have no injurious effects on any crops except potatoes. With this crop, it may favor scab. When potatoes are to be grown, lime should be applied as far away from the potatoes in the rotation as possible.

The most satisfactory way of spreading limestone is with limestone distributors. They distribute the lime evenly and the cost of distribution is low. There are a number of limestone distributors on the market, varying in price from $50 to $100. Home made spreaders may be made at a much lower cost. The two common types of spreaders are the two-wheel broadcast distributor and the endgate attachment. The two-wheel broadcast types are of varying design and they differ in operating success. The better machines are provided with mechanical agitators in the hopper which prevent clogging. Large pieces of limestone should be removed to avoid danger of breaking the machine. The endgate spreader can be attached to any farm wagon and it may be changed from one wagon to another thus saving time.

A very satisfactory home made limestone spreader was recently devised by the Michigan Agricultural Experiment Station. It is called the Simplex Lime Spreader and is attached to a wagon box. It is simple in design and may be built by a good mechanic at a cost of approximately $10 to $12. Blue prints and instruction for making this machine may be secured from the Agricultural Extension Department of Iowa State College at a cost of 20 cents.

Limestone is sometimes applied by the use of the manure spreader and if only small amounts are to be applied, it may serve the purpose very well. Manure or wet straw should be placed in the spreader first to prevent the lime from sifting thru. The use of a limestone distributor generally gives much more satisfactory results, however. The spreading of lime by hand from a wagon is laborious and does not permit of an even distribution of the material. It is not a desirable practice except on very small areas, such as gardens or lawns.

THE COST OF FERTILIZERS

Fertilizing materials vary considerably in price from year to year and only average figures can be given. Freight charges are not included in the figures given below. These are often heavy, particularly with rock phosphate and limestone, and should be considered.

Acid phosphate in carload lots of 15 tons minimum is quoted at $26.20 per ton, freight prepaid, a five percent discount being allowed for cash.

Potassium fertilizers cost about $50 per ton delivered.

Nitrate of soda costs about $70.50 per ton.

Limestone costs from 50 cents to $1.50 per ton in carload lots, f. o. b. the quarry. A carload varies from 40 to 60 tons. The actual cost of the application must include freight charges which will, of course vary with the distance. Limestone should be secured from the nearest shipping point in order to keep down the freight costs.

Complete commercial fertilizers are variable in price, depending upon the plant food content or the guarantee analysis of the material. The higher grade materials are higher in price, but they are usually more economic. The standard 2-12-2 brand which contains the same total amount of plant food as acid phosphate (16 percent) altho it has less phosphorus of course, is quoted at $37.75 per ton for 1925 as compared to $26.20 for the acid phosphate.

HOW TO DETERMINE FERTILIZER VALUE

The value of applying any fertilizer may be determined accurately only by measuring the crop increase secured from its use and by subtracting the total cost of the fertilizer from the total value of the crop increase, using the market price of the crop. It is not enough merely to note that the fertilizer gave a better looking crop, or that the crop was certainly larger. The actual increase should be measured, which can only be done by weighing the crop. Estimated yields are apt to be quite inaccurate. The farmer who wishes to learn what his soil needs and to know that his soil has responded profitably to the use of a fertilizer must measure the yields. The yield on the fertilized plot or strip must of course be compared with the yield on a similar area unfertilized. Subtracting the latter, the increase is determined. This increase may then be calculated on an acre basis.

COMPLETE FERTILIZERS WHICH MAY BE TESTED IN IOWA

Of the many complete commercial fertilizers which may be tested on Iowa soils, only the following are recommended. Low grade fertilizers are not recommended because their cost per unit of plant food and cost of application is relatively greater. The character of soil and kind of crop must be considered in selecting a fertilizer. Clay soils are not apt to need potassium, while sandy soils may particularly need this element. For use on the former, the fertilizer may be incomplete, containing only nitrogen and phosphorus. Phosphorus is needed in the largest amounts in all fertilizers for all crops on all kinds of soils. Nitrogen may be left out of the fertilizer when it is used as a top dressing for legumes. For other general crops, nitrogen may be increased to advantage and often more potassium may be added with profit.

For general farm crops in Iowa, the following brands may be used on the average soil:

2-12-2
2-12-4
2-12-6
2-14-2
2-16-2

Probably the 2-12-2 or the 2-16-2 brands are the most desirable for tests on most Iowa soils. On the lighter textured soils it may be desirable to use the 2-12-4 or the 2-12-6

For top dressing legumes or for crops which do not require nitrogen or for certain garden or truck crops such as root crops, the following may be employed:

0-12-6
0-14-4

For market garden or truck crops the following brands may be used:

3- 8 -6
3-12-4
4- 8 -6
4-12-0

For so-called organic soils, namely, peats or mucks, the following may be tested:

0-18-24
0-10-10
2-8-16
0-10-12

WHERE TO BUY LIMESTONE

Limestone is sold by the following companies:

Bettendorf Stone Co., Davenport, Iowa—Quarry at Bettendorf.

Burlington Quarry Co., Burlington, Iowa—Quarry at Montrose.

Dearborn Sons, Stone City, Iowa—Quarry at Stone City.

Decorah Stone Products, Decorah, Iowa—Quarry at Decorah.

Dolese Bros., 10 S. LaSalle St., Chicago, Ill.—Quarry at Buffalo, Iowa.

Eagle Point Lime Works, Dubuque, Iowa—Quarry at Dubuque.

Iowa Limestone Co., Des Moines, Iowa—Quarry at Alden.

Hawkeye Quarries Co., Cedar Rapids, Iowa—Quarry at Stone City and Glory, Iowa.

Keokuk Stone & Construction Co., Keokuk, Iowa—Quarry at Keokuk.

LeGrand Stone Co., LeGrand, Iowa—Quarry at LeGrand.

Linwood Cement Co., Davenport, Iowa—Quarry at Buffalo.

Marquette Stone Products Co., Marquette, Iowa—Quarry at Marquette.

McManus Quarries Co., Keokuk, Iowa—Quarry at McManus and Tucker, Ia.

Mt. Pleasant Crushed Stone Co., Mt. Pleasant, Iowa — Quarry at Mt. Pleasant

Murphy Construction Co., Omaha, Neb.—Quarry at Louisville, Neb.

National Stone Co., Omaha, Neb.—Quarry at Louisville, Neb.

Peru Stone & Cement Co., 308 W. 5th St., Des Moines, Iowa—Quarry at Peru, Iowa.

Reinert Bros. Construction Co., St. Joseph, Mo.—Quarry at St. Joseph, Mo.

River Products Co., Iowa City, Iowa—Quarry at Coralville, Iowa.

Shellrock Limestone Co., Shellrock, Iowa—Quarry at Shellrock.